The Yield, Quality, and Nutrient Relationships of Celery as Affected by Commercial Fertilizer

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THE YIELD, QUALITY, AND NUTRIENT RELATIONSHIPS OF CELERY AS AFFECTED BY COMMERCIAL FERTILIZER

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Author of thesis

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INTRODUCTION

Celery production has become an important factor in the economy of certain areas in Utah. In 1949 over 400 acres were harvested with an average yield of 800 crates per acre, the average return per crate being $1.80. This amounts to over half a million dollars. The crop serves as a valuable cash crop, creates a demand for hand labor, and serves as an important consumer of commercial fertilizer.

Little experimental work has been done on the fertilizer requirements of celery in Utah. At the present time estimates of fertilizer need are being based upon grower practices and work done in other areas. Information is needed on the amount of each fertilizer element needed to give optimum yields under Utah conditions.

The quality of Utah celery in the past has been one of its chief selling points in competition with celery from other areas. If a good market for Utah celery is to be maintained, the quality must be maintained or improved. In the last few years some Utah celery has been pithy and tough which is an expression of poor quality. There is widespread feeling among growers that quality of celery can be improved by fertilizer practice. As yet there is very little experimental evidence on this relationship.

This study was arranged to obtain information as to the relationships that exist between yield, quality, the nutrient element content, and applied fertilizer.

REVIEW OF LITERATURE

The fertilizer requirements of celery are high. These requirements vary under different conditions. Skinner (1930) recommended up to 8000 pounds of 5-2-8 fertilizer per acre under Florida conditions on Leon fine sand, with emphasis being placed on high nitrogen and potash and low phosphate.

Bockenback (1939) on Florida everglade peat soil gained best response with application of 60 pounds N, 120 pounds of P_2O_5, and 240 pounds of K_2O per acre. The low need for applied nitrogen was due to the high content of available nitrogen in this organic soil.

Lorenz (1946) secured profitable results under California conditions with applications of 400 pounds of nitrogen on mineral soils in the Santa Monica area, but obtained no response to phosphate and potash.

Crandall (1937), under Rhode Island conditions, obtained favorable response to 80 pounds nitrogen, 180 pounds P_2O_5, and 180 pounds K_2O applied in addition to 10-15 tons of manure.

Nylund (1942) reported best yield from 1000 pounds of 0-12-24 on peat soils in Minnesota.

Comin (1931) reported good response to 65 pounds of nitrogen in Ohio, large response to phosphate, and only small response to potash on old peat soils.

Parker (1939) showed increased yield with supplementary applications of 300 pounds of nitrogen in addition to a basic application of two tons of a 6-6-5 fertilizer. This supplementary nitrogen greatly increased the nitrate nitrogen content of the leaf tissue.

Only limited work has been done on the nutrient relationships of celery. Carolus (1938) reported 393 parts per million of NO_3, 408 parts per million of P, 5000 parts per million of K_2O, and 1050 parts per million of CaO in the green petiole tissue of celery during a period of rapid growth. This work was done in Virginia.

Lorenz (1945) reported that increasing amounts of an 8-8-4 fertilizer increased the nitrate, phosphate, and potash content of celery petiole tissue with the largest increase being made in the nitrate nitrogen content.

The celery soils in Utah are mineral. The work done on celery on other mineral soils suggest high requirements for nitrogen and potash fertilizers with a low requirement for phosphate fertilizer. Utah growers are at present using a large amount of phosphate fertilizer which seems excessive in light of the work done in other areas.

METHODS

Experimental Design

The experiment was set up with three levels each of nitrogen, phosphorus, and potassium in all possible combinations, giving a total of 27 individual fertilizer treatments. In Table I the three levels of each fertilizer and application information are given. These treatments were set up as a 3^3 factorial type design, arranged with three incomplete blocks of nine treatments each in each replication. The 27 treatments were replicated six times. The incomplete blocks were randomized to superimpose insecticide treatments over the experimental area. The insecticide treatments were so arranged that there were two replications of three treatments. Appendix Figure I

Table 1. The amount, form, and method application of fertilizer applied on celery.

Treatment symbol	Pounds per acre	Mineral element
N_0	107	N)
N_1	214	N) (1)
N_2	321	N)
P_0	0	P_2O_5)
P_1	80	P_2O_5) (2)
P_2	160	P_2O_5)
K_0	0	K_2O)
K_1	120	K_2O) (3)
K_2	240	K_2O)

(1) Applied according to the following:

Date	Lbs. nitrogen N_0	N_1	N_2	Form of fertilizer	Method of application
5-4-49	20	40	60	ammonium sulphate	broadcast before planting
7-9-49	27	54	81	ammonium sulphate	side dressed
8-8-49	20	40	60	ammonium sulphate	by hand in furrow bottom
9-2-49	20	40	60	ammonium sulphate	by hand in furrow bottom
9-15-49	20	40	60	liquid amm. nitrate	by hand in furrow bottom

(2) Applied broadcast before planting as treble superphosphate.

(3) Applied broadcast before planting as muriate of potash.

is a field plan for reference which shows the exact location of each treatment. There were separate experiments for testing special soil ammendments, minor elements, and celery varieties which are not included in this study.

Field Work

The experimental plots were located on a field one-half mile south of American Fork. This field is mapped in the soil survey of the area as McBeth loam. In 1948 the experimental area was planted in cabbage and had a uniform application of five hundred pounds per acre of 10-12-10 fertilizer. The cabbage was not harvested but plowed under as a green manure crop.

On May 4, 1949, all of the phosphorus and potassium and one-fourth of the originally planned nitrogen was applied broadcast to the 8 x 60 foot plots, and then the entire field was disked to thoroughly incorporate the applied fertilizer into the soil. Plants of the Ferry Morse 10B strain of the Utah variety of celery from Moapa Valley, Nevada, were transplanted into the field on May 31 and June 1. They were so transplanted that there were four rows, two feet apart, centered within each plot. Four guard rows were planted on either side of the test area; approximately fifteen feet were planted at the upper end and ninety feet at the lower end of the field as guard strips.

The second one-fourth of the originally planned nitrogen was applied July 18-19. This fertilizer was drilled in bands, half of it going on each side and approximately three inches away from the celery plants and two inches deep. It was impossible to adjust the fertilizer distributor to the exact desired rate and so instead of a 20 pound nitrogen base application, a 27 pound base rate was used. The third one-fourth of the originally planned nitrogen was applied August 8 and was applied in bands in the bottom of the irrigation furrow by hand. The fourth application of originally planned nitrogen was applied September 11 by hand in bands in the bottom of the irrigation furrows. Two weeks later, representatives of the Utah Agricultural Experiment Station, the Utah Growers Cooperative, and the farmer in charge of the growing of the crop met and decided that another application of nitrogen at the same rate as the previous four should be applied in liquid form. This was applied because the packing plant field men estimated that the celery would not reach market maturity for two weeks. This fifth application of nitrogen fertilizer was applied as liquid ammonium nitrate at the same rates of nitrogen content as the original nitrogen application. The liquid concentrate (20-0-0) was mixed with about ten parts water and applied in the bottom of the irrigation furrow by means of rubber hose attached to watering cans. It was planned that the field would be irrigated immediately after the application, but this was not done.

Nutrient Relationship Sampling

Tissue samples were taken July 9, August 8, September 2, and the final one on October 4, at time of harvest. The samples were taken by sampling at least ten plants per plot. On the first three sampling dates the youngest mature petiole was selected in an attempt to obtain tissue of approximately the same physiological age. At harvest time the tissue sample was selected from the outer petioles of trimmed celery stalks. This gave an older tissue on the last sampling date.

For the nutrient relationship study the six replications were combined into three. Replications 1 and 2, 3 and 4, and 5 and 6 were grouped together in pairs to reduce the chemical determinations to three replications. Two samples were taken from each plot of the six replications and combined by paired replications according to fertilizer treatment. This gave two samples from an effective plot twice the original size. The tissue samples at each date were washed in water, dried, and stored for analysis during the winter months.

Yield

It was planned to take weight records of the entire yield of each plot. However, the application of liquid ammonium nitrate resulted in serious burning of the outside petioles of much of the celery. The higher the nitrogen level, the more serious the burn. As a result of this burning a great deal of trimming was necessary to obtain a commercial grade of celery. In order to obtain an estimate of yield without trimming the celery to eliminate burned petioles, the packing crew of the Utah Growers Cooperative was taken into the field and the celery was sized, ignoring the burned petioles, and counted in place. It is believed that this gave the best estimate of yield that could be obtained, considering the serious burn. Three different size groupings were counted: large, $1\frac{1}{2}$-2 dozen stalks to the crate; medium, $2\frac{1}{2}$-$3\frac{1}{2}$ dozen stalks to the crate; and small, 4-$4\frac{1}{2}$ dozen stalks to the crate. The stalks in each of these size groupings were given an average weight according to the fraction of a crate represented by each stalk. This value was multiplied by the number of stalks in each size grouping occurring in a plot and added to give an expression of total yield. The yield data reflect a weighted average of each stalk of celery in crates per acre as governed by the size of the celery.

Quality

An attempt to estimate quality was made with an adaption of the pea tenderometer. The pea tenderometer was first filled with celery stalks to obtain the shearing stress necessary to cut through them. This volume was found to be in excess of the capabilities of the instrument, so it was decided to cut the celery petioles into longitudinal strips, $\frac{1}{4}$ inch square by means of a shoestring potato cutter. Sections for the tenderometer were obtained by selecting complete sections having one side the outside of the celery petiole and containing vascular bundles. To obtain samples for the pea tenderometer, mature petioles from the outside of commercial stalks of celery were selected. Three samples of six petioles each were taken from each plot and one section from each petiole was selected after going through the shoestring potato cutter for placement in the pea tenderometer. The six strips of tissue were just sufficient to make one layer, $\frac{1}{4}$ inch thick in the bottom of the shearing compartment. This procedure was found to give shearing stress values well within the range of the tenderometer.

Laboratory Analysis

Two tenths of a gram of air-dried celery petiole tissue was extracted with 50 ml. of 0.05 N acetic acid. This suspension was shaken for ten minutes, filtered, and the chemical determinations made on the filtrate. Extraction with 0.05 N acetic acid gave comparable values with extraction by two percent acetic acid as recommended by Carolus (1938) and did not give as much interference in the determination of potassium and calcium with the use of the flame photometer. Table 2 shows the average percent of total phosphate, potassium, and calcium extracted at each sampling date by the extraction procedure.

Nitrate nitrogen was estimated by the phenoldisulphonic acid method as modified by Ulrich (1948). The procedure for nitrate nitrogen in the absence of excess chloride was used. Chlorides were found to range from two and one-half percent to four percent. To compensate for chloride interference with the nitrate determination, potassium chloride equivalent to 3.2 percent chloride in the plant material was added to all standards. A maximum error of eight percent due to chloride interference was obtained by this procedure. The chloride content of enough samples was determined to indicate no correlation of chloride content with fertilizer treatment. By using this method a great saving in time was attained.

Phosphate content was determined by the ammonium molybdate method as modified by Ulrich (1948). In the place of stannous chloride as a reducing agent, 1, 2, 4 - aminonaphthalsulfonic acid was used after the method of Fiske and Sudbarrow (1925). This was found to produce a much more stable color.

Potassium and calcium were determined with the use of a Beckman flame photometer. This instrument is inherently quite variable. The weakest point is the atomizer which is subject to frequent clogging. Due to the clogging it is impossible to make an absolute calibration

Table 2. The average percent extraction of total phosphate, potassium, and calcium by sampling dates.

Element	Sampling dates 7-9	8-5	9-2	10-4
PO_4	64.0	80.2	82.7	82.5
K	94.0	99.4	91.4	91.9
Ca.	82.0	43.1	38.0	35.2

of the instrument, so a comparison technique was developed to compensate for this variability.

A standard was selected from the center of the range to be investigated. This central standard was adjusted to the desired transmission value, usually 50 percent transmission, with the use of the slit width control. This was done with the variable sensitivity control set at approximately the mid point. The standards covering the desired range were each compared with the central standard, always setting the instrument to 50 percent transmission with the central standard in place.

By this method, curves relating transmission values to the concentration of desired element were developed. After the curve was once established an unknown needed only to be compared with a central standard. This reduced the number of standards which had to be kept on hand. Four central standards, with their attending curves of varying levels, were sufficient to provide close comparisons with any unknown within the useful range of the instrument.

In practice at least two determinations should be made on each sample. By doing this large fluctuations of the instrument are easily corrected. These two readings should not vary over one percent transmission for accurate work. Table 3 gives the instrument settings used in the analysis of potassium and calcium.

Table 3. Instrument settings and standards used on flame photometer

Element	Wave length	Air pressure	Oxygen pressure	Gas pressure + butane	Slit width	Central standard	Transmission
	mμ.	lbs/sq.in.	inches mercury	cm. isopropyl alcohol	mm.	p.p.m.	percent
K	767	28	28	1	0.015	100	50
Ca	626	28	28	1	0.16	100	50
					0.22	50	50
					0.46	25	50
					0.6	12.5	50

RESULTS

Soil analysis

In Table 4 are presented the analyses of soil samples collected from the experimental field before the fertilizer treatments were applied.

The analyses show that the soil was originally quite high in nitrogen and phosphate and comparatively low in potassium.

Yield

The yield of celery in relation to fertilizer treatments is shown in Table 5. The N_1 and P_1 treatments on the average had a large number of plants in excess of the other treatments. Since the yield was estimated by a weighted average of each plant in the plot, plots with high numbers of plants would of necessity have high yields. Thus, it was found necessary to adjust the yield to uniform stand. The adjusted yield shows that nitrogen had very little affect on yield. The high level of nitrogen was actually lower than the other two. This lack of response to nitrogen may have been due to the physiological burn caused by the late application of liquid nitrogen fertilizer. It is reasonable to assume that the high nitrogen treatments were injured sufficiently to stop growth after this application of nitrogen. This injury might thus account for the lack of yield response to nitrogen. With phosphorus the difference in yield between the P_0 and P_1 level is approaching significance. There was no difference between yields from the P_1 and P_2 level which indicates that 200 pounds per acre of phosphate fertilizer was sufficient for optimum plant growth. Potassium

Table 4. Soil analysis

Location north to south	ph	Soluble salts percent	Organic matter percent	$CaCO_3$ (lime) percent	CO_2 Soluble			NH_4Ac Soluble	Mechanical composition		
					PO_4 p.p.m.	N as NO_3 p.p.m.	K p.p.m.	K p.p.m.	Sand percent	Silt percent	Clay percent
0- 60'	8.0	.13	3.2	35	25	33	20	65			
60-120'			2.4	29	34	20	40	51			
120-180'	7.9	.15	3.2	28	60	48	25	75	47	33	20
180-240'			3.3	28	64	47	25	90			
240-300'	7.8	.13	3.6	31	38	80	25	78			
300-360'			4.8	34	28	54	55	104			
360-420'	7.8	.12	5.2	34	29	88	25	62			
420-480'			5.6	34	20	75	35	72			
480-540'	7.9	.10	5.6	36	18	33	15	65	15	55	30
540-600'			5.5	36	21	68	30	96			
600-660'	8.0	.19	5.6	35	18	45	25	77			
660-720'			5.4	39	19	28	45	74			

Table 5. The stand, yield, and tenderometer values of celery.
(averages of main effects)

Treatment	Plants/ acre	Yield in crates/acre unadjusted	adjusted	Tenderometer shearing stress
				lbs./sq. inch
N_0	38640	1200	1218	137
N_1	39910	1249	1219	135
N_2	38790	1196	1208	132
P_0	38370	1156	1184	132
P_1	39910	1261	1231	139
P_2	39060	1229	1231	133
K_0	38990	1183	1186	136
K_1	39160	1199	1197	135
K_2	39190	1265	1260	132
$LSD_{.05}$		80	50	16
$LSD_{.01}$		107	67	22

fertilizer gave a highly significant yield increase and the evidence indicates that even more than 400 pounds per acre of muriate of potash might be beneficial. There were no significant interactions between the different fertilizers and yield.

Quality

There were no significant effects of fertilizer on tenderometer readings as an estimate of quality. Table 5 shows a tendency for lower shearing stress values with additions of nitrogen and potassium. The differences are small and not significant. There are two assumptions that might be put forth: either applied fertilizer has very little effect in improving quality under the observed conditions, or the method that was used to estimate quality was not sufficiently accurate. A better method of estimating quality should be developed to throw further light on this problem.

In appendix Table I are the analyses of variances of number of plants, tenderometer readings, yield, and covariance of yield. These analyses have been used as a basis for selecting points of discussion.

Nutrient Relationship Data

In Table 6 is presented the season averages for each of the fertilizer main effects as they influence the various soluble nutrient components.

Nitrate nitrogen

Increasing levels of nitrogen fertilizer were highly significant in increasing nitrate nitrogen content. Phosphate and potassium had no significant effect on nitrate nitrogen content.

Table 6. Mineral nutrient content of petiole tissue, soluble in 1:250 extract with 0.05 N acetic acid. (season averages of main effects in percent of dry weight)

Treatment	$N^{(1)}$	PO_4	K	Ca
N_0	0.24	1.12	2.58	0.89
N_1	0.30	1.18	2.67	0.86
N_2	0.35	1.18	2.63	0.88
P_0	0.29	1.15	2.60	0.88
P_1	0.30	1.16	2.63	0.89
P_2	0.30	1.17	2.64	0.86
K_0	0.29	1.18	2.28	0.85
K_1	0.29	1.16	2.68	0.89
K_2	0.30	1.14	2.91	0.89
$LSD_{.05}$	0.03	0.03	0.10	0.04
$LSD_{.01}$	0.04	0.04	0.14	0.05

(1) nitrate nitrogen

Table 7 shows the significant nitrogen x phosphate interaction on nitrate nitrogen content. The effect of nitrogen fertilizer in increasing nitrate nitrogen is nearly the same at the P_0 and P_2 levels. At the P_1 level, N_1 is just as effective in increasing nitrate nitrogen content as is the N_2 level of nitrogen fertilizer.

Table 8 shows the effect of the fertilizer treatments on nitrate content at the four sampling dates. There was a highly significant nitrogen by date interaction on nitrate nitrogen content. Nitrogen fertilizer was more effective in increasing nitrate nitrogen content at the fourth sampling date than on the previous three. This great increase of nitrate nitrogen content with applied nitrogen on the fourth date may be an expression of the fifth fertilizer application, which was applied in liquid form and may indicate that the liquid fertilizer was more effective in entering the plant. On the other hand, this may indicate that growth was stopped allowing the nitrates to accumulate. Some of this difference may also be due to the differences between the physiological ages of the first three sampling dates as compared with the fourth within the plants where high injury had been suffered. There were no significant interactions of phosphorus or potassium fertilizer by date on nitrate nitrogen content. The large drop in nitrate nitrogen content with season may be due to a dilution of the soluble content caused by large tissue growth. The vascular system does not increase as much in weight as does the rest of the petiole as the season advances.

Table 7. Nitrate nitrogen content of petiole tissue, soluble in 1:250 extract with 0.05 N acetic acid. (season averages in percent of dry weight)

Treat- ment	Treatments P_0	P_1	P_2	Average
N_0	0.24(1)	0.21	0.26	0.24(2)
N_1	0.28	0.35	0.28	0.30
N_2	0.35	0.34	0.34	0.35
Av.	0.29(2)	0.30	0.30	

(1) $LSD_{.05}$ 0.04 $LSD_{.01}$ 0.06

(2) $LSD_{.05}$ 0.03 $LSD_{.01}$ 0.04

Table 8. Nitrate nitrogen content of petiole tissue, soluble in 1:250 extract with 0.05 N acetic acid. (averages by sampling dates in percent dry weight)

Treatment	Sampling dates			
	7-9-49	8-8-49	9-2-49	10-4-49
N_0	0.37	0.33	0.15	0.11
N_1	0.41	0.44	0.17	0.20
N_2	0.39	0.51	0.19	0.28
P_0	0.38	0.41	0.18	0.19
P_1	0.40	0.43	0.16	0.21
P_2	0.38	0.45	0.16	0.19
K_0	0.39	0.42	0.17	0.20
K_1	0.39	0.43	0.17	0.18
K_2	0.39	0.44	0.16	0.21
Date average	0.39	0.43	0.17	0.20
$LSD_{.05}$	0.05	0.09	0.04	0.05
$LSD_{.01}$	0.07	0.12	0.06	0.07

Phosphate

Phosphate fertilizer had no significant effect upon phosphate content (table 8). There was, however, a trend for phosphate fertilizer to increase phosphate content. Nitrogen fertilizer was highly significant in increasing phosphate content but the N_2 level was no more effective than the N_1 . Potassium fertilizer was highly significant in depressing phosphate content with the depressing effect increasing with the amount of potassium applied.

Table 9 shows the significant NP interaction upon phosphate content. Nitrogen fertilizer was more effective in increasing phosphate content than the phosphate fertilizer itself.

Table 10 shows the significant NK interaction upon phosphate content. The effect of nitrogen fertilizer in increasing phosphate content was uniform at the K_0 and K_2 levels, but at the K_1 level, N_1 was more effective in increasing phosphate content than was N_2.

Table 11 shows the significant PK interaction upon phosphate content. Applied phosphorus was more effective in increasing phosphate content at the K_1 level than at the K_0 and K_2 levels of potassium fertilizer.

Table 12 shows the effect of various fertilizer treatments on phosphate content at the four sampling dates. There was a significant nitrogen by date interaction. This is due to the fact that nitrogen fertilizer was more effective in increasing phosphate content in the latter part of the season. The interactions of phosphate and potassium fertilizers by date were not significant.

Table 9. Phosphate content of petiole tissue, soluble in 1:250 extract with 0.05 N acetic acid. (season averages in percent of dry weight)

Treat-ment	Treatments P_0	P_1	P_2	: Average
N_0	1.10(1)	1.11	1.16 :	1.12(2)
N_1	1.18	1.19	1.16 :	1.18
N_2	1.18	1.18	1.20 :	1.18
Av.	1.15(2)	1.16	1.17	

(1) $LSD_{.05}$ 0.04 $LSD_{.01}$ 0.06

(2) $LSD_{.05}$ 0.03 $LSD_{.01}$ 0.04

Table 10. Phosphate content of petiole tissue, soluble in 1:250 extract with 0.05 N acetic acid. (season averages in percent of dry weight)

Treat- ment	Treatments K_0	K_1	K_2	: Average
N_0	1.16(1)	1.09	1.11 :	1.12(2)
N_1	1.18	1.21	1.14 :	1.18
N_2	1.20	1.18	1.16 :	1.18
Av.	1.18(2)	1.16	1.14	

(1) $LSD_{.05}$ 0.04 $LSD_{.01}$ 0.06

(2) $LSD_{.05}$ 0.03 $LSD_{.01}$ 0.04

Table 11. Phosphate content of petiole tissue, soluble in 1:250 extract with 0.05 N acetic acid. (season averages in percent of dry weight)

Treat- ment	Treatments K_0	K_1	K_2	: Average
P_0	1.18(1)	1.12	1.14 :	1.15(2)
P_1	1.19	1.16	1.15 :	1.16
P_2	1.18	1.19	1.15 :	1.17
Av.	1.18(2)	1.16	1.14	

(1) $LSD_{.05}$ 0.04 $LSD_{.01}$ 0.06

(2) $LSD_{.05}$ 0.03 $LSD_{.01}$ 0.04

Table 12. Phosphate content of petiole tissue, soluble in 1:250 extract with 0.05 N acetic acid. (averages by sampling dates in percent of dry weight)

Treat-ment	Sampling dates			
	7-9-49	8-6-49	9-2-49	10-4-49
N_0	0.95	1.24	1.33	0.96
N_1	0.96	1.27	1.48	0.99
N_2	0.97	1.30	1.45	1.02
P_0	0.96	1.26	1.40	0.97
P_1	0.95	1.27	1.41	1.01
P_2	0.97	1.28	1.45	0.99
K_0	0.96	1.29	1.48	1.00
K_1	0.97	1.27	1.40	1.00
K_2	0.95	1.25	1.38	0.97
Date average	0.96	1.27	1.42	0.99
$LSD_{.05}$	0.07	0.06	0.10	0.07
$LSD_{.01}$	0.10	0.08	0.13	0.09

Potassium

Potassium fertilizer (Table 6) had a highly significant effect upon increasing potassium content. Nitrogen fertilizer showed a tendency to increase it, but the effect was not significant.

Table 13 shows the significant NK interaction upon potassium content. Potassium fertilizer was more effective in increasing potassium content at the N_1 level than at the N_0 and N_2 level of nitrogen fertilizer.

Table 14 shows the significant PK interaction upon potassium content. Applied phosphorus fertilizer had a tendency to decrease potassium content at the K_0 level and increase potassium content at the K_2 level of potassium fertilizer.

Table 15 shows the effect of the various fertilizer treatments on potassium content by date. There were significant nitrogen by date, phosphate by date, and potassium by date interactions. The significant nitrogen by date interaction on potassium content is due to the fact that nitrogen fertilizer was significant in increasing the potassium content only on the first sampling date. The significant phosphorus by date interaction on potassium content is due to the fact that the potassium fertilizer was more effective in increasing the potassium content of the plant in the early part of the season. This may be due to the fact that potassium is very soluble and readily taken up in luxury consumption.

Calcium

Potassium fertilizer was significant in increasing calcium content (Table 6). The K_1 level was just as effective as the K_2 level.

Table 13. Potassium content of petiole tissue, soluble in 1:250 extract with 0.05 N acetic acid. (season average in percent of dry weight)

Treat-ment	Treatments K_0	K_1	K_2	:	Average
N_0	2.30(1)	2.66	2.78	:	2.58(2)
N_1	2.26	2.71	3.05	:	2.67
N_2	2.29	2.67	2.92	:	2.62
Av.	2.28(2)	2.68	2.91		

(1) $LSD_{.05}$ 0.18 $LSD_{.01}$ 0.23

(2) $LSD_{.05}$ 0.10 $LSD_{.01}$ 0.14

Table 14. Potassium content of petiole tissue, soluble in 1:250 extract with 0.05 N acetic acid. (season average in percent of dry weight)

Treat-ment	Treatments K_0	K_1	K_2	:	Average
P_0	2.36(1)	2.64	2.80	:	2.60(2)
P_1	2.22	2.71	2.97	:	2.63
P_2	2.26	2.68	2.97	:	2.64
Av.	2.28(2)	2.68	2.91		

(1) $LSD_{.05}$ 0.18 $LSD_{.01}$ 0.23

(2) $LSD_{.05}$ 0.10 $LSD_{.01}$ 0.14

Table 16. Potassium content of petiole tissue, soluble in 1:250 extract with 0.05 N acetic acid. (averages by sampling dates in percent of dry weight)

Treat-ment	Sampling dates			
	7-9-49	8-6-49	9-2-49	10-4-49
N_0	3.00	2.97	2.30	2.04
N_1	3.29	3.01	2.50	1.89
N_2	3.23	2.96	2.41	1.90
P_0	3.24	2.85	2.39	1.90
P_1	3.12	3.04	2.39	1.99
P_2	3.15	3.07	2.44	1.89
K_0	2.74	2.54	2.20	1.65
K_1	3.29	3.05	2.41	1.98
K_2	3.49	3.36	2.61	2.20
Date average	3.17	2.98	2.41	1.94
$LSD_{.05}$	0.23	0.24	0.30	0.16
$LSD_{.01}$	0.30	0.33	0.41	0.22

Table 16 shows the effects of the various fertilizer treatments on calcium content by dates. The only significant interaction was potassium by date. This relation is due to the fact that potassium was more effective in increasing the soluble calcium content in the latter part of the season.

In appendix Table II are the analyses of variances of the nutrient data. These analyses have been used to indicate points for discussion. Only statistically significant effects have been discussed.

Correlations of nutrient content and yield

Table 17 gives the random correlation, independent of treatments, of the soluble mineral nutrient content and yield by the individual sampling dates. On the first sampling date the correlation was positive but not significant for all nutrients. On the second sampling date high nitrate nitrogen content was correlated with high yield, high phosphate content was correlated with low yields. On the third sampling date high nitrate nitrogen content was very closely correlated with high yield. On the fourth sampling date high phosphate content was correlated with low yields.

In appendix Tables III, IV, and V all the results are presented as means for the individual fertilizer treatments.

Table 16. Calcium content of petiole tissue, soluble in 1:250 extract with 0.05 N acetic acid. (averaged by sampling dates in percent of dry weight)

Treat-ment	Sampling dates			
	7-8-49	[illegible]	9-2-49	[illegible]
N_0	1.65	0.68	0.46	0.53
N_1	1.81	0.68	0.40	0.54
N_2	1.84	0.73	0.42	0.54
P_0	1.84	0.72	0.43	0.54
P_1	1.04	0.69	0.44	0.60
P_2	1.82	0.68	0.41	0.53
K_0	1.82	0.69	0.41	0.50
K_1	1.86	0.70	0.44	0.57
K_2	1.85	0.71	0.44	0.59
Date average	1.85	0.70	0.43	0.55
$LSD_{.05}$	0.13	0.13	0.09	0.08
$LSD_{.01}$	0.18	0.17	0.11	0.10

Table 17. Random correlation, independent of treatment, of mineral nutrient content and yield by sampling dates.

Soluble	Sampling dates			
nutrient	7-9-49	8-8-49	9-2-49	10-4-49
N	.122	.379*	.660**	.242
PO_4	.258	-.335*	-.132	-.409*
K	.212	-.024	-.177	-.194

DISCUSSION

Yield

The lack of yield response to nitrogen is a serious limitation of this investigation. Comin (1931), Crandall (1937), Lorenz (1946), and Parker (1939) all showed high returns from applied nitrogen fertilizer on mineral soils. Even with organic soils, Beckenbach (1939) showed responses to nitrogen. The lack of yield response to nitrogen fertilizer may be due to two causes. The soil analysis showed high available nitrates at the beginning of the season and this supply may have been adequate. It is the opinion of the author, however, that the lack of yield response was due to the physiological burn caused by the fifth fertilizer application of liquid ammonium nitrate. An estimate of the nitrogen effect may be obtained from the nutrient relationship data. The correlation coefficient of nitrate nitrogen content with yield at the various sampling dates (Table 17) indicates that wherever a plot was high in nitrate nitrogen, it also produced high yield, and since applied nitrogen fertilizer was very effective in increasing nitrate nitrogen content, we may use this as a basis for estimating the beneficial effects of nitrogen fertilizer. The regression coefficient of yield upon nitrate nitrogen content for the third sampling date is 548 crates per percent nitrate nitrogen. The increase in nitrate nitrogen at this sampling date due to applied nitrogen fertilizer was .04 percent nitrate nitrogen. This would indicate an increase of 22 crates per acre of celery due to the high nitrogen fertilizer. This would not have been significant, but it does indicate that nitrogen fertilizers might be effective in increasing the yield of celery.

The use of phosphate fertilizers gave a slight increase in yield which was not significant. The third level of phosphate was no more effective in increasing yield than was the second level, which indicates that high levels of phosphate fertilizer were not profitable under those conditions. Since there was such a high level of available soil phosphate at the beginning of the season (Table 4), a large increase in yield due to phosphate fertilizer would not have been expected. Lorenz (1946) and Skinner (1930) both showed that celery has low requirements for phosphate fertilizer.

Potassium fertilizers gave highly significant yield increases. This is the first time experimental evidence has been obtained to indicate a need for potassium fertilizers under Utah soil conditions. It has been assumed that there was sufficient potassium being released through weathering processes in our soils to supply crop demand. In analyzing this situation three pertinent facts must be recognized. These soils have been cropped intensively for long periods. Celery has high fertilizer requirements and excessive leaching is caused by the frequent irrigation necessary for raising celery. This study indicates that more work needs to be done on other crops that have high fertilizer requirements to determine if this potassium response was due to chance or whether it is an extensive problem.

The yield data as presented in Table 5 may be higher than actual values. This is due to the fact that the celery was sized and graded in the untrimmed state and this may have led to high values. However, the comparisons between treatments should be valid. Another year's work should be carried on to determine if this field sizing of celery gives an accurate estimate of yield. This could be done by field sizing and then taking a weight measurement on the same plots.

Quality

This study indicates that nitrogen and potassium may be beneficial in improving some aspects of quality. More work needs to be done to see if this difference can be measured more accurately and if the difference was actually due to fertilizer or just due to chance. Some refinements of method are definitely needed in investigating quality factors. One improvement on the method might be to chop celery into one quarter inch cubes to allow a more uniform sample for tenderometer determinations. Another might be the adaptation of the tenderometer to measure greater shearing forces.

Nutrient Relationships

The data obtained indicate that nitrogen fertilizer was effective in increasing nitrate nitrogen at all dates sampled. The largest increase due to nitrogen fertilizer was on the fourth sampling date. This may be an expression of injury resulting from burn incurred from the late application of liquid ammonium nitrate fertilizer. This high accumulation of nitrate may be due to the increased availability of the ammonium nitrate, but it is the author's opinion that the large increase of nitrate nitrogen with nitrogen fertilizer was due to the high nitrogen plots being stopped in growth so that there was an accumulation of unused nitrate. Some of this increase may also be due to the fact that older tissues were sampled on the last date. It should be noted that the liquid ammonium nitrate would not produce this burn under normal fertilizing conditions. The burn was due to the way in which it was applied; the liquid was too concentrated due possibly to the fact that its application was not immediately followed by an irrigation.

Phosphate fertilizers were not very effective in increasing the phosphate content of the plants. This may have been due to the fact that the original level in the soil of available phosphorus was very high. Nitrogen did significantly increase the phosphate content of the plant and potassium significantly decreased the phosphate content of the plant. Since the phosphate content of the plant was negatively correlated with yield in the last part of the season, part of the beneficial response of potassium may have been due to its depressing effect upon phosphate. This depressing effect on phosphate may not have actually been a decrease in amount of phosphate taken up, but may have resulted from a dilution of phosphate by greater plant growth on the potassium plots.

One of the major difficulties of a study of this type is to obtain similar samples throughout the entire season. In this study there was an attempt made to obtain a tissue of approximately the same physiological age by sampling the youngest mature petioles at each of the first three sampling dates. The fourth sampling date represents a much older tissue than the previous three and in this respect it is difficult to correlate the fourth sampling date with the previous three. This difficulty should be eliminated in future studies.

The laboratory methods of analysis of tissue samples were not completely satisfactory. The phenoldisulphonic method for nitrate nitrogen determination is subject to rather serious criticism. A good many compounds present in plant material interfer with the nitrate determination. The effect of chlorides is widely discussed in the literature. However, it is the opinion of the author that organic material interfers much more with this determination than do chlorides, especially in plant material where there is a rather uniform chloride content. Much of the high nitrate nitrogen experimental error was due to laboratory analysis and does not necessarily reflect a sampling variation in the field. This point should be investigated thoroughly to determine the exact extent of sampling and analytical errors. The phosphate determination was found to be quite satisfactory. The use of the flame photometer for potassium and calcium determination is excellent where large numbers of analyses are to be made. The use of this instrument greatly facilitates analytical procedures and results in great savings of time. There are numerous variables that need to be worked out in its use. Very little information is available at present to determine the extent of interferences encountered with various extraction procedures and the effects of one ion on another. Preliminary work indicates that the ion effects tend to be additive. High calcium tends to give high potassium values and high potassium tends to give high calcium values. This may partially explain the effect of high potassium fertilizers in increasing soluble calcium content.

The correlations of nutrient content with yield (Table 17) indicate that the greatest need for phosphate and potassium is in the early part of the season and that the greatest need for nitrogen is just before the plant reaches maturity.

SUMMARY AND CONCLUSIONS

A field experiment was run on celery to determine the effects of nitrogen, phosphate, and potassium fertilizers on the yield, quality, and nutrient relationships of celery. The nutrient relationships were studied and the results of four sampling dates discussed.

The conclusions are as follows:

1. The nitrogen picture on yield is not known. The fifth application of liquid ammonium nitrate produced such serious physiological burn that in all probability the high nitrogen plots were lower in yield than they might have been. The high significant correlation coefficient of nitrate nitrogen content with yield, coupled with the fact that applying nitrogen was effective in increasing nitrate nitrogen content, leads the author to believe that nitrogen would have been effective in increasing yield had not the burning occurred.

2. Phosphate did not significantly improve yield, although there was a small yield increase with higher amounts of phosphate fertilizer. The third level of phosphate was no more effective in increasing yield than was the second. This indicates that high levels of phosphate fertilizer were not profitable. The original soil analyses (Table 4) show high available phosphorus. Due to the high available phosphate in the soil, a large increase in yield due to phosphate fertilizer would not have been expected.

3. There was a highly significant increase in yield with applied potassium. This is the first time that positive yield increases have been observed with the use of potassium fertilizers in this area. The optimum level of potassium fertilizer is not known and more work

should be done to find out if higher levels of potassium fertilizer would increase yield.

4. There were no significant differences between fertilizer applications with respect to tenderness of petiole tissue as measured with a pea tenderometer. There were trends which indicated that increasing nitrogen and potassium increases tenderness. More information is needed to clarify this problem. Other methods of estimating quality should be investigated.

5. Applied nitrogen fertilizer was effective in increasing nitrate content of celery petiole tissue.

6. Applied phosphorus was not significantly effective in increasing phosphate content, but nitrogen significantly increased phosphate content and potassium significantly decreased phosphate content.

7. Applied potassium was very effective in increasing potassium content.

8. Nitrogen should probably be applied periodically with more frequent applications at dates approaching maturity. Phosphorus and potassium should probably be applied early in the season, and late side dressings of potassium may actually reduce yields.

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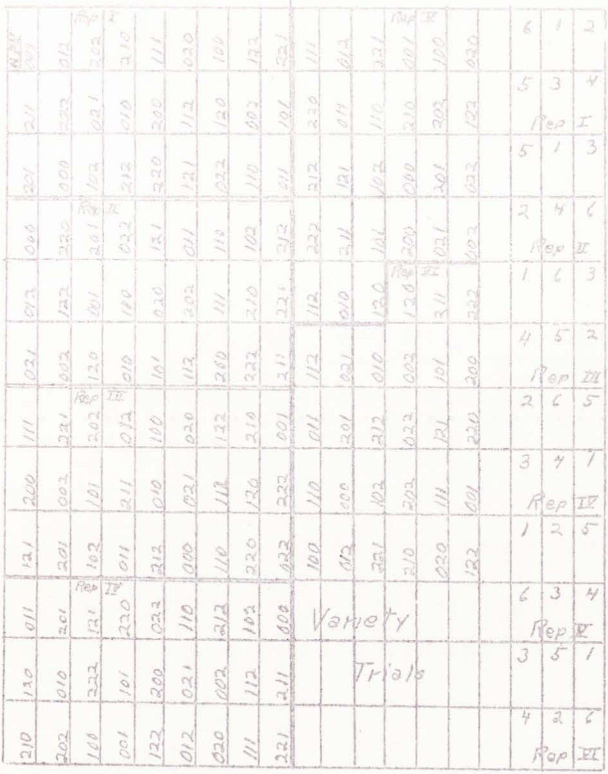
A P P E N D I X

Appendix Figure 1. 1949 Celery Field Plan



Symbol	#/acre	Element
N_0	107	N
N_1	214	N
N_2	321	N
P_0	0	P_2O_5
P_1	80	P_2O_5
P_2	160	P_2O_5
K_0	0	K_2O
K_1	120	K_2O
K_2	240	K_2O

Special Treatments

1 Check
2 Sulfuric acid 2,000 #/acre
3 Minor elements
  $MnSO_4$, $ZnSO$ 50 #/acre
  $CuSO_4$, borax 25 #/acre
4 Sulfuric acid - Minor elements
5 Sulfur 650 #/acre
6 Gypsum 2000 #/acre

Appendix Table I. The analysis of variance of number of plants, yield, tenderometer readings, and covariance of yield of celery.

Source (1)	df		Number of plants	Yield M sq.	Tenderometer M sq.	Covariance M. sq.
Blocks	8		792.08	4.119*	18546.7	1.238
Fertilizers	24		252.79	1.997	3334.2	1.000
N		2	1105.00	2.025	6540.5	.082
N_L		1	12.68	.014		.094
N_Q		1	1052.70	4.036		.070
P		2	1370.00	6.617*	13190.0	1.671
P_L		1	277.12	6.087	641.0	2.508
P_Q		1	1092.70	7.148*	25739.0*	.836
K		2	27.00	4.123	4771.5	3.561*
K_L		1		7.363*		6.051**
K_Q		1		.883		1.071
NP		4	157.50	1.890	955.2	.772
NK		4	306.25	.657	1357.5	.302
PK		4	92.25	.531	584.5	.831
NPK		6	223.50	2.380	3204.8	.961
Error	48		385.17	1.757	5384.0	.713(2)
Total	80					

(1) L = Linear
Q = Quadratic
N = Nitrogen
P = Phosphorus
K = Potassium

(2) df 47

Appendix Table II. The analysis of variance of nitrate nitrogen, phosphate, potassium and calcium content of celery.

Source(1)	df		N(2) M sq.	PO_4 M sq.	K M sq.	Ca M sq.
Blocks	8		.6069**	.1814**	1.7801**	.2560
Fertilizers	24		.3275**	.0569	2.2218**	.0297
N	2		2.6912**	.2442**	.4782	.0682
N_L		1	5.2909**	.4095**		
N_Q		1	.0915	.0790*		
P	2		.0200	.0379	.0847	.0473
P_L		1				
P_Q		1				
K	2		.0187	.1002**	22.0299**	.0936
K_L		1		.2002**	43.0798**	.1568*
K_Q		1		.0002	.9800	.0305
NP	4		.3546**	.0353	.2038	.0393
N_LP_L		1	.0696	.0302		
N_LP_Q		1	.1110	.0003		
N_QP_L		1	.0150	.0828*		
N_QP_Q		1	1.2234**	.0278		
NK	4		.0119	.0573*	.4566	.0096
N_LK_L		1		.0041	.3754	
N_LK_Q		1		.0690	.0725	
N_QK_L		1		.0002	1.3290*	
N_QK_Q		1		.1560**	.0497	
PK	4		.0580	.0356	.5093	.0095
P_LK_L		1		.0005	1.2970*	
P_LK_Q		1		.1192*	.0014	
P_QK_L		1		.0201	.7105	
P_QK_Q		1		.0028	.0284	
NPK	6		.1195	.0116	.5763	.0101
Error (A)	48		.0868	.0185	.3140	.0338

(continued on next page)

(1) L = Linear
Q = Quadratic
N = Nitrogen
P = Phosphorus
K = Potassium

(2) Nitrate nitrogen

Appendix Table II. continued:

Source (1)	df		N(2) M sq.	PO_4 M sq.	K M sq.	Ca M sq.
Dates	3					
L		1	25.1708**	.4779**	146.6107**	136.9164**
Q		1	.0273	22.1223**	2.9592**	64.7306**
C		1	12.4612**	1.4503**	1.0743**	1.8768**
Blocks x Date	24		.3017**	.1154**	.4542**	.1653
Fert. x Date	72		.0806*	.0186	.2480	.0308
ND		6	.4429**	.0541*	.5656	.0300
N_LD_L		1	.6024**	.0372	1.3266*	
N_LD_Q		1	.0575	.0600	.0028	
N_LD_C		1	1.8847**	.0373	.6654	
N_QD_L		1	.0843	.0145	.7332	
N_QD_Q		1	.0072	.0584	.0740	
N_QD_C		1	.0210	.1176*	.5876	
PD		6	.0604	.0113	.4138	.0180
P_LD_L		1	.0244		.2185	
P_LD_Q		1	.0238		1.4134*	
P_LD_C		1	.1943		.4423	
P_QD_L		1	.0063		.1768	
P_QD_Q		1	.0952		.0435	
P_QD_C		1	.0188		1.0952*	
KD		6	.0286	.0237	.5722	.0184
K_LD_L		1			1.4107*	
K_LD_Q		1			.0420	
K_LD_C		1			1.4209*	
K_QD_L		1			.4036	
K_QD_Q		1			.1060	
K_QD_C		1			.0499	
Error (b)	144		.0520	.0186	.2072	.0354
Sampling errors						
Date 1	81		.0372	.0160	.2186	.0222
Date 2	81		.0296	.0079	.1169	.0214
Date 3	81		.0102	.0142	.0729	.0043
Date 4	81		.0008	.0041	.0131	.0016
Total	647					

(1) L = Linear
Q = Quadratic
C = Cubic
N = Nitrogen
P = Phosphorus
K = Potassium
D = Date

(2) Nitrate nitrogen

Appendix Table III. The stand, yield, tenderometer readings, and season averages of soluble mineral nutrient content of celery.

Treatment NPK	Plants/ acre	Crates/ acre	Adj. crates/ acre	Tenderometer Shearing stress lbs/sq.in.	Season averages in percent dry weight N(1)	PO_4	K	Ca
000	38623	1144	1164	134	0.26	1.14	2.46	0.84
001	35937	1067	1186	150	0.23	1.05	2.64	0.93
002	40220	1296	1255	132	0.25	1.10	2.61	0.88
010	38551	1129	1151	148	0.20	1.20	2.25	0.86
011	41128	1249	1175	143	0.23	1.04	2.72	0.91
012	38115	1224	1262	135	0.21	1.10	2.64	0.96
020	39277	1217	1224	139	0.25	1.16	2.17	0.90
021	36482	1152	1251	134	0.26	1.17	2.62	0.90
022	39712	1328	1307	135	0.28	1.14	3.08	0.88
100	37607	1114	1171	134	0.26	1.18	2.12	0.84
101	39531	1188	1174	136	0.26	1.19	2.74	0.84
102	39785	1207	1183	133	0.31	1.16	3.01	0.88
110	41055	1362	1291	144	0.33	1.18	2.32	0.84
111	42072	1296	1157	138	0.34	1.24	2.54	0.89
112	41273	1417	1338	134	0.37	1.15	3.22	0.88
120	38369	1153	1182	125	0.31	1.18	2.33	0.84
121	41092	1261	1184	141	0.28	1.19	2.86	0.85
122	38732	1256	1243	131	0.25	1.11	2.91	0.90
200	37897	1189	1235	130	0.33	1.22	2.49	0.88
201	38841	1091	1102	132	0.38	1.15	2.56	0.93
202	37135	1114	1188	126	0.35	1.17	2.79	0.92
210	39748	1142	1119	132	0.35	1.19	2.10	0.89
211	38115	1197	1235	132	0.29	1.20	2.88	0.92
212	39458	1340	1328	141	0.38	1.14	3.03	0.88
220	40075	1205	1170	139	0.33	1.19	2.28	0.82
221	39531	1299	1284	130	0.37	1.22	2.58	0.83
222	38587	1197	1218	122	0.33	1.18	2.93	0.87
$LSD_{.05}$		240	150	48	0.08	0.08	0.30	0.10
$LSD_{.01}$		321	201	66	0.11	0.10	0.40	0.15

(1) Nitrate nitrogen

Appendix Table IV. The soluble nitrate nitrogen and phosphate content of celery petioles on individual sampling dates. (treatment averages in percent dry weight)

NPK	7-9 N(1)	8-8 N(1)	9-2 N(1)	10-4 N(1)	7-9 PO_4	8-8 PO_4	9-2 PO_4	10-4 PO_4
000	0.40	0.32	0.24	0.09	0.93	1.23	1.37	0.97
001	0.38	0.28	0.14	0.14	0.90	1.25	1.17	0.88
002	0.37	0.31	0.15	0.11	0.95	1.21	1.29	0.95
010	0.32	0.28	0.10	0.09	0.97	1.31	1.47	1.05
011	0.44	0.29	0.10	0.07	0.92	1.10	1.18	0.96
012	0.31	0.33	0.09	0.09	0.93	1.29	1.22	0.96
020	0.35	0.35	0.15	0.15	0.93	1.29	1.41	0.99
021	0.36	0.37	0.16	0.13	0.97	1.29	1.43	1.00
022	0.41	0.43	0.14	0.13	1.00	1.22	1.45	0.92
100	0.34	0.41	0.14	0.16	0.97	1.35	1.46	0.96
101	0.37	0.39	0.14	0.15	0.99	1.24	1.54	0.98
102	0.44	0.40	0.19	0.20	1.01	1.25	1.43	0.95
110	0.41	0.48	0.21	0.24	0.97	1.22	1.53	0.99
111	0.43	0.55	0.15	0.25	0.96	1.36	1.60	1.02
112	0.51	0.51	0.19	0.3[illegible]	0.98	1.22	1.39	1.01
120	0.45	0.47	0.12	0.21	0.93	1.22	1.53	1.05
121	0.40	0.40	0.20	0.14	0.96	1.31	1.46	1.03
122	0.34	0.37	0.14	0.16	0.88	1.25	1.36	0.94
200	0.40	0.44	0.14	0.36	0.99	1.34	1.56	0.98
201	0.42	0.63	0.25	0.22	0.93	1.19	1.35	1.06
202	0.35	0.48	0.24	0.31	0.97	1.29	1.42	1.02
210	0.40	0.53	0.20	0.26	0.87	1.35	1.51	1.04
211	0.32	0.38	0.16	0.30	1.02	1.30	1.46	1.04
212	0.50	0.54	0.19	0.31	0.89	1.27	1.37	1.01
220	0.43	0.46	0.21	0.22	1.06	1.26	1.46	0.98
221	0.40	0.60	0.22	0.25	1.06	1.26	1.46	1.03
222	0.29	0.58	0.13	0.31	0.94	1.28	1.54	0.99
$LSD_{.05}$	0.16	0.28	0.13	0.16	0.21	0.18	0.30	0.21
$LSD_{.01}$	0.20	0.37	0.17	0.21	0.30	0.24	0.39	0.27

(1) Nitrate nitrogen

Appendix Table V. The soluble potassium and calcium content of celery petioles on individual sampling dates. (treatment averages in percent of dry weight)

NPK	7-9 K	8-8 K	9-2 K	10-4 K	7-9 Ca	8-8 Ca	9-2 Ca	10-4 Ca
000	2.79	2.76	2.43	1.88	1.84	0.66	0.39	0.48
001	3.06	3.10	2.39	2.01	1.98	0.65	0.43	0.67
002	3.08	2.75	2.32	2.29	1.80	0.62	0.63	0.55
010	2.70	2.64	1.95	1.72	1.76	0.76	0.48	0.46
011	3.18	3.17	2.24	2.28	1.82	0.64	0.43	0.76
012	3.20	2.97	2.19	2.22	1.83	0.69	0.63	0.68
020	2.45	2.55	2.03	1.65	1.83	0.72	0.41	0.62
021	3.17	3.11	2.21	1.96	1.93	0.67	0.52	0.46
022	3.38	3.64	2.97	2.32	1.86	0.70	0.37	0.56
100	2.53	2.42	2.09	1.46	1.83	0.63	0.40	0.48
101	3.67	2.74	2.64	1.90	1.74	0.73	0.40	0.47
102	3.75	3.32	2.73	2.22	1.89	0.72	0.39	0.52
110	2.66	2.50	2.46	1.66	1.77	0.65	0.38	0.54
111	3.04	2.85	2.38	1.88	1.82	0.66	0.42	0.67
112	4.03	3.90	2.72	2.23	1.85	0.70	0.42	0.54
120	2.95	2.50	2.34	1.53	1.93	0.62	0.37	0.43
121	3.40	3.38	2.66	1.99	1.75	0.67	0.40	0.57
122	3.54	3.45	2.51	2.16	1.75	0.73	0.42	0.69
200	3.42	2.54	2.29	1.72	1.78	0.92	0.37	0.45
201	3.23	2.86	2.18	1.98	1.99	0.71	0.52	0.50
202	3.64	2.98	2.40	2.14	1.76	0.79	0.45	0.68
210	2.30	2.46	2.07	1.58	1.98	0.59	0.43	0.57
211	3.66	3.30	2.53	2.03	1.89	0.87	0.44	0.50
212	3.33	3.53	2.98	2.29	1.84	0.68	0.37	0.64
220	2.84	2.46	2.15	1.68	1.71	0.63	0.43	0.48
221	3.18	2.92	2.49	1.72	1.74	0.66	0.40	0.54
222	3.46	3.66	2.64	1.96	1.92	0.72	0.41	0.45
$LSD_{.05}$	0.69	0.72	0.90	0.48	0.39	0.38	0.25	0.23
$LSD_{.01}$	0.90	0.99	1.23	0.66	0.52	0.51	0.32	0.30